

**UTILITY PATENT  
APPLICATION TRANSMITTAL**

(Only for new nonprovisional applications  
under 37 CFR 1.53(b))

Attorney Docket No.

**980055**

Total Pages

First Named Inventor or Application Identifier

**Koji NOZAKI and Ei YANO**

Express Mail Label No.

Check Box, if applicable ☐ Duplicate

**APPLICATION ELEMENTS FOR:**

**POLYMER COMPOUND FOR A CHEMICAL  
AMPLIFICATION RESIST AND A FABRICATION  
PROCESS OF A SEMICONDUCTOR DEVICE  
USING SUCH A CHEMICAL AMPLIFICATION RESIST**

**ADDRESS TO: Assistant Commissioner for Patents  
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Washington, D.C. 20231**

1. ☒ Fee Transmittal Form (Incorporated within this form)  
(Submit an original and a duplicate for fee processing)
2. ☒ Specification Total Pages [42]
3. ☒ Drawing(s) (35 USC 113) Total Sheets [1]
4. ☒ Oath or Declaration Total Pages [2]
  - a. ☒ Newly executed (original or copy)
  - b. ☐ Copy from prior application (37 CFR 1.63(d))  
(for continuation/divisional with Box 17 completed).
    - i. ☐ Deletion of Inventor(s)  
Signed statement attached deleting inventor(s) named in prior application,  
see 37 CFR 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation by reference (useable if box 4b is checked)  
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under  
Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby  
incorporated by reference therein.
6. ☐ Microfiche Computer Program (Appendix)
7. ☐ Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
  - a. ☐ Computer Readable Copy
  - b. ☐ Paper Copy (identical to computer copy)
  - c. ☐ Statement Verifying identity of above copies

**ACCOMPANYING APPLICATION PARTS**

8. ☒ Assignment Papers (cover sheet and document(s))
9. ☐ 37 CFR 3.73(b) Statement (when there is an assignee) ☒ Power of Attorney

# UTILITY PATENT APPLICATION TRANSMITTAL

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PAGE 2 OF 3

10. ☐ English translation Document (if applicable)

11. ☐ Information Disclosure Statement ☐ Copies of IDS Citations

12. ☐ Preliminary Amendment

13. ☒ Return Receipt Postcard (MPEP 503)

14. ☐ Small Entity Statement(s) ☐ Statement filed in prior application  
Status still proper and desired.

15. ☒ Claim for Convention Priority ☒ Certified copy of Priority Document(s)

a. Priority of \_\_\_\_\_ application no. \_\_\_\_\_ filed on \_\_\_\_\_ is claimed under 35 USC 119.  
The certified copies/copy have/has been filed in prior application Serial No. \_\_\_\_\_.  
(For Continuing Applications, if applicable).

16. ☐ Other \_\_\_\_\_

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:

☐ Continuation ☐ Division ☐ Continuation-in-part (CIP) of prior application no. \_\_\_\_/\_\_\_\_

FEE TRANSMITTAL	Number Filed	Number Extra	Rate	Basic Fee
The filing fee is calculated below				\$790.00
Total Claims	23 - 20	3	x \$22.00	66.00
Independent Claims	4 - 3	1	x \$82.00	82.00
Multiple Dependent Claims			\$270.00	
Basic Filing Fee				938.00
Reduction by 1/2 for small entity				
Fee for recording enclosed Assignment			\$40.00	40.00
TOTAL				\$978.00

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**PAGE 3 OF 3**

☒ A check in the amount of \$978.00 is enclosed to cover the filing fee of \$938.00 and the assignment recordation fee of \$40.00.

☐ Please charge our Deposit Account No. **01-2340** in the total amount of \_\_\_\_\_ to cover the filing fee and the \_\_\_\_\_ assignment recordation fee. A duplicate of this sheet is attached.

☒ The Commissioner is hereby authorized to charge payment for any additional filing fees required under 37 CFR 1.16 or credit any overpayment to Deposit Account No. **01-2340**. A duplicate of this sheet is attached.

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**SUBMITTED BY**

Typed or Printed Name **Le-Nhung McLeland**

Reg. No. **31,541**

Signature *by Ronald T. Naughton*, Reg. No. *26,414* Date: **January 29, 1998**

LNM/yap

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SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, Koji Nozaki, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan and Ei Yano, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan have invented certain new and useful improvements in

POLYMER COMPOUND FOR A CHEMICAL AMPLIFICATION  
RESIST AND A FABIRICATION PROCESS OF A SEMICONDUCTOR  
DEVICE USING SUCH A CHEMICAL AMPLIFICATION RESIST

of which the following is a specification : -

1     TITLE OF THE INVENTION

          POLYMER COMPOUND FOR A CHEMICAL  
AMPLIFICATION RESIST AND A FABRICATION PROCESS OF A  
SEMICONDUCTOR DEVICE USING SUCH A CHEMICAL  
5     AMPLIFICATION RESIST

BACKGROUND OF THE INVENTION

          The present invention generally relates to a  
resist composition that can be developed by a basic  
10    developing liquid and a fabrication process of a  
semiconductor device using such a resist composition.

          With the advancement in the art of device  
miniaturization, recent semiconductor integrated  
circuits designated as LSIs or VLSIs are now patterned  
15    with sub-micron line widths. Further, intensive  
investigations are being made on so-called sub-  
halfmicron devices that use a minimum pattern width of  
smaller than 0.5  $\mu\text{m}$ .

          In order to fabricate such sub-halfmicron  
20    devices, it is essential to reduce the wavelength of  
the optical radiation that is used for exposing a  
pattern on a semiconductor substrate, from a  
conventional, normal ultraviolet wavelength to a far-  
ultraviolet wavelength. Further, investigations are  
25    being made also on the exposure process that uses a  
deep ultraviolet wavelength radiation. Associated  
with such a shift in the wavelength of the optical  
radiation used for photolithography, there is an  
urgent demand for a resist composition that shows a  
30    reduced optical absorption in such a very short  
wavelength band and simultaneously a high dry etching  
resistance and a high sensitivity.

          In recent years, intensive studies have been  
made on the photolithography that uses a novel optical  
35    source of KrF excimer laser. A KrF excimer laser  
produces an optical radiation with a wavelength of 248  
nm, and the technology of the KrF excimer laser

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On the other hand, recent attempts of forming semiconductor devices of still higher integration density such as Gbit DRAMs, have urged an investigation on the photolithography that uses a still shorter wavelength optical radiation of 193 nm

1 wavelength band produced by an ArF excimer laser. In  
the photolithographic process that uses such a very  
short wavelength optical radiation, the problem of  
strong optical absorption by the resist is inevitable  
5 as long as a phenolic polymer resin is used for the  
resist base. Thus, there is an urgent demand for a  
resist that is applicable to such a very short-  
wavelength optical radiation.

While there are various chemical  
10 amplification resists studied for application to an  
exposure process conducted with the optical radiation  
of 193 nm wavelength, most of the conventionally  
studied resists are based on a methacrylic resin that  
has an ester group called polycyclic alicyclic group.  
15 Examples thereof are adamantane, isobornane,  
tricyclodecane, and others. See for example, Nozaki,  
K., et al, Chem. Mater., 1994, 6, 1492-1498, Nakano,  
K., et al, Proc. SPIE, 1994, 2195, 194-204, and Allen,  
R. D., et al, Proc. SPIE, 1994, 2438, 474-485. The  
20 foregoing conventional resists successfully realize  
the necessary dry-etching resistance that is essential  
for a resist, by incorporating alicyclic ester group  
into the base resin.

On the other hand, the foregoing  
25 conventional resists have suffered from the problems,  
associated with the use of the alicyclic group in the  
resin, such as a peeling-off of the resist during the  
developing process or an insufficient dissolving of  
the exposed area to an alkaline developer. In order  
30 to overcome the foregoing problems, there are  
proposals such as incorporation of carboxylic acid  
unit into the base resin or using a diluted developing  
liquid. Further, there are proposals for mixing an  
alcohol such as isopropyl alcohol to the developer.

35 Further, there is a report of a chemical  
amplification resist composition that solves the  
foregoing problems successfully (Nozaki, K., et al.,

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1 the resist film becoming soluble to the basic solution  
upon a deprotection of the acid-cleavable protective  
group from the side chain of the monomer, wherein the  
carboxyl group contains a protective group represented  
5 by a formula (I),



10 where n is an integer of 1 - 4, R is any of a hydrogen  
atom, an alkyl group, an alkoxy group, or an  
alkoxycarbonyl group connected to an arbitrary  
position excluding a third position that forms an  
15 ester bonding.

The acid-sensitive polymer used for the base  
resin of the resist composition of the present  
invention includes various polymers ranging from  
various copolymer compounds containing a monomer unit  
20 that includes therein the foregoing lactone structure  
and the additional acidic functional group attached to  
the resist side chain and including the acid-cleavable  
protective group, to a terpolymer including the  
foregoing monomer unit and other arbitrary monomer  
25 units.

It should be noted that the polymer used in  
the present invention preferably contains at least one  
monomer unit that contains the foregoing carboxyl  
group including the protective group. The monomer  
30 unit may be selected from any of acrylate monomer  
unit, methacrylate monomer unit, vinylphenol monomer  
unit, N-substitute maleimide monomer unit, and styrene  
monomer unit. Alternatively, the monomer unit may be  
the one that has an ester group including therein a  
35 monocyclic alicyclic hydrocarbon. Monomer units that  
includes a structure of adamantyl group or norbornyl  
in the polycyclic alicyclic hydrocarbon part are most

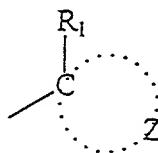
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1     preferable.

          Further, it is preferred that the resist  
composition of the present invention shows an optical  
absorption, when used to form a resist film on an SiO<sub>2</sub>  
5     substrate, of 1.75 or less in the deep-ultraviolet  
wavelength band of 180 - 300 nm, which is used in the  
conventional exposure process. When the absorption is  
increased above the foregoing value, the transmittance  
of the resist film decreases substantially and the  
10    patterning becomes difficult.

          In the acid-sensitive copolymer noted above,  
it is also preferable that a monomer unit, which  
causes a polymerization with the monomer unit that  
includes the carboxyl group in which the foregoing  
15    lactone protective group is included, includes another  
carboxyl group having the acid-cleavable protective  
group. Thus, the acid-sensitive copolymer of the  
present invention may include a monomer unit having a  
first carboxyl group that includes the foregoing  
20    lactone part as a first protective group and further a  
monomer unit having a second carboxyl group that  
includes the foregoing acid-cleavable protective group  
as a second protective group.

          It should be noted that the foregoing  
25    monomer unit having the second carboxyl group  
preferably includes the carboxyl group such that the  
protective group causes a deprotection in response to  
the acid released by the photoacid generator, which  
may be added to a side chain of the same monomer unit,  
30    and that the protective group of the carboxyl group  
has a structure represented by the formula (II),



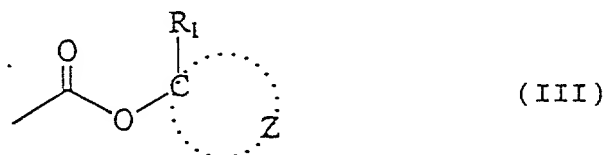
(II)

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1 wherein  $R_1$  represents a substituted or unsubstituted  
alkyl group and may have a straight chain or a  
branched chain containing 1 - 4 carbon atoms, while Z  
5 represents the atoms that are necessary to complete  
the alicyclic hydrocarbon group together with the  
carbon atoms attached to  $R_1$ .

There are various forms possible for the  
second carboxyl group, while the preferable form is  
represented according to the formula (III) below,

10



15 wherein  $R_1$  and Z are defined already in the formula  
(II).

The preferred resist composition of the  
present invention is supplied in a form of solution  
dissolved into a solvent, which is selected from a  
20 group of ethyl lactate, methylamylketone, methyl-3-  
methoxypropionate, ethyl-3-ethoxypropionate,  
propyleneglycolmethylether acetate and a mixture  
thereof. The resist solution may further contain  
butylacetate,  $\gamma$ (gamma)-butyrolactone, propyleneglycol  
25 methylether and a mixture thereof as additional  
solvent.

In another aspect of the present invention,  
there is provided a method of forming a resist pattern  
comprising the steps of:

30 coating a resist composition of the present  
invention as set forth before on a substrate to form a  
resist film;

exposing the resist film to an exposure  
optical radiation that induces a decomposition of the  
35 photoacid generator in the resist composition; and

developing the exposed area in a basic  
solution.

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1 soluble to the basic solution before the exposure  
process.

It is recommended to set the proportion of  
the photoacid generator to fall in the range of 0.1 -  
5 50 wt% with respect to the polymer weight, more  
preferably to 1 - 15 wt%. Further, the weight average  
molecular weight of the polymer used in the present  
invention may fall in the range of 2,000 - 1,000,000,  
more preferably the range of 5,000 - 50,000.

10 The additional solvent to be added to the  
resist solution may not be necessary when the  
solubility of the solutes is good. When the  
solubility of the solutes is poor, on the other hand,  
it is recommended to use such an additional solvent  
15 with a proportion of 1 - 30 wt%, more preferably 10 -  
20 wt%, with respect to the main solvent.

The basic solution used for the developer  
may include an aqueous solution of a metal hydroxide  
of group I or II metals such as KOH or an aqueous  
20 solution of an organic base not containing a metal  
ion, such as tetraalkylammonium hydroxide.  
Particularly, the use of tetramethylammonium hydroxide  
(TMAH) is preferred. Further, various additives such  
as a surfactant may be added for improving the  
25 efficiency of developing.

Other objects and further features of the  
present invention will become apparent from the  
following detailed description when read in  
conjunction with the attached drawings.

30

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIGS.1A - 1F are diagrams showing the  
fabrication process of a semiconductor device  
according to an embodiment of the present invention.

35

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT [GENERAL]

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1           The present invention relates to a chemical  
amplification resist composition that forms a positive  
resist pattern on a substrate upon a developing  
process conducted by a basic aqueous solution.

5           The resist composition of the present  
invention includes:

(a) an acid-sensitive film-forming polymer  
insoluble to a basic aqueous solution and having a  
carboxyl group on a side chain of a monomer unit that  
10 constitutes the film-forming polymer, the carboxyl  
group containing a protective group, the film-forming  
polymer further having an additional acidic functional  
group different from the carboxyl group on a side  
chain of a monomer unit constituting the film-forming  
15 polymer, the additional acidic functional group  
containing an acid-cleavable protective group, which,  
upon deprotection from the side chain, causes a change  
in the film-forming polymer to become soluble to an  
alkaline aqueous solution; and

20 (b) a PAG releasing an acid in response to an  
optical exposure, which acid causing a deprotection of  
the acid-cleavable protective groups, in response to a  
decomposition caused in turn in response to an  
absorption of an exposure optical radiation,

25           wherein the film-forming polymer contains a  
lactone part represented by the formula (I) or (II) as  
the protective group of the carboxyl group.

          The protective groups release protonic acids  
upon the deprotection, and the resist composition  
30 achieves a high sensitivity as a result of the  
chemical amplification thus occurred. After the  
deprotection of the protective groups, the exposed  
area in the resist film becomes soluble to alkalis,  
and it becomes possible to form a positive resist  
35 pattern from the resist film by conducting a  
development process while using a basic solution for  
the developer.

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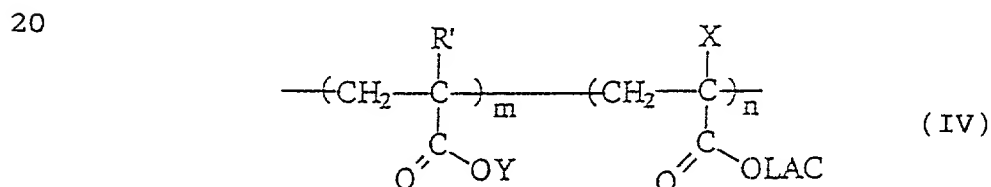




1 source such as an ArF excimer laser is used for the  
optical source, the transparency of the resist at the  
wavelength of 193 nm becomes an especially important  
factor in addition to the dry etching resistance. In  
5 such a case, it is recommended to use a polymer,  
particularly an acrylate or methacrylate polymer,  
which contains a polycyclic alicyclic hydrocarbon  
having a high dry etching resistance such as adamantyl  
group or norbornyl group, in addition to the cleavable  
10 ester group.

The foregoing acrylate or methacrylate polymer as well as other acid-sensitive polymers may have a wide range of molecular weight (weight-average molecular weight,  $M_w$ ), preferably in the range between 2,000 and 1,000,000, more preferably in the range between 3,000 and 50,000.

In the case of using an acrylate or methacrylate polymer, the formula of the polymer is represented as



25 wherein R' represents a hydrogen atom or an arbitrary  
substituent such as halogen, an alkyl group, a methyl  
group, and the like; Y represents an arbitrary acid-  
cleavable protective group such as tBu group, a  
30 tetrahydropyranyl group, an isobornyl group, 2-methyl-  
2-adamantyl group, and the like; m and n represent a  
normalized mole ratio of each monomer unit ( $m + n = 1$ );  
X represents, when not specified otherwise, a hydrogen  
atom, a halogen atom such as Cl or Br, a lower grade  
alkyl group such as a methyl group or ethyl group, or  
35 a cyano group; and LAC represents the lactone part of  
the formula (I).

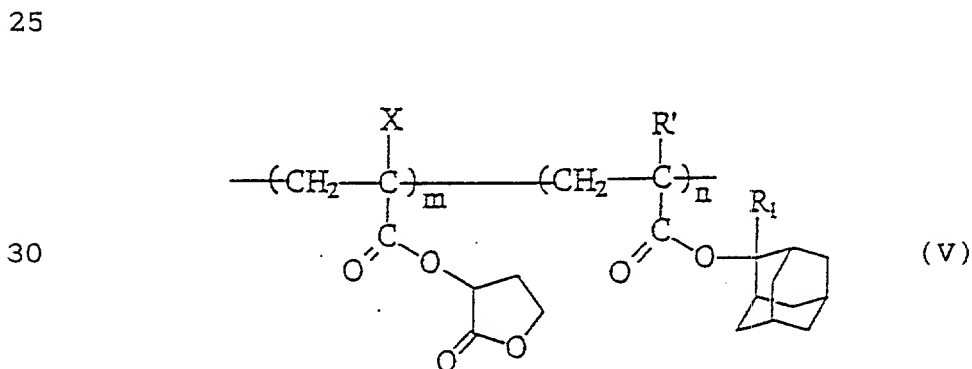
The acrylate or methacrylate polymer of the

1 present invention can be easily synthesized by a  
commonly used polymerization process. For example,  
the polymer may be formed advantageously by heating  
monomers in the presence of AIBN (2, 2'-  
5 azobisisobutyronitril) which is used commonly for a  
free radial initiator. Further, the acid-sensitive  
polymers other than the foregoing acrylate or  
methacrylate polymer may be prepared according to a  
well established process.

10 In the resist composition of the present  
invention as a base resin, it is preferable to use a  
monomer unit having the structure of the formula (II)  
for the protective group of the acidic functional  
group.

15 While there are various possible forms for  
the protected acidic functional groups, it is  
preferable to use a compound having the formula (III)  
for this purpose.

20 In more detail, the copolymer formed of the  
monomer units that have a carboxyl group containing  
therein a protective group, is represented by a  
formula (V). More specifically, the acid-sensitive  
polymer may be formed of the copolymer represented by  
the formula (V) as



35 wherein  $R_1$ ,  $R'$ ,  $X$ ,  $m$  and  $n$  are already defined, the  
substituent  $R'$  and  $X$  may be identical or different and  
preferably formed of a hydrogen atom or a methyl

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1 basic aqueous solution. Most preferably, the monomer  
unit is contained with a proportion of 40 - 60 mol%.

It should be noted that the mechanism of the  
chemical amplification process for the foregoing  
5 copolymer resist is identical to that of a general  
chemical amplification process. The copolymer further  
has an advantageous effect of solubility to alkalis  
provided by the lactone group in the monomer unit.

It is well known that a polymer of acrylate  
10 or methacrylate shows a high transparency in the deep  
ultraviolet wavelength band. As the copolymer  
represented by the formula (VI) does not contain a  
chromophore showing a large molar extinction  
coefficient in the wavelength band of 190 - 250 nm in  
15 the two ester parts thereof, it is possible to obtain  
a high sensitivity resist composition applicable to a  
deep ultraviolet exposure process from the foregoing  
copolymer, by adding a suitable amount of PAG.

When the foregoing polymer is used for the  
20 base resin of a resist film, there proceed following  
reactions in the exposed part of the resist  
simultaneously or separately, by consuming a small  
amount of  $H_2O$  contained in the resist film. Thereby,  
the reaction stops when  $H_2O$  in the exposed region are  
25 consumed. As a protonic acid is regenerated after the  
deprotection of the adamantyl group, the resist film  
shows a very high sensitivity.

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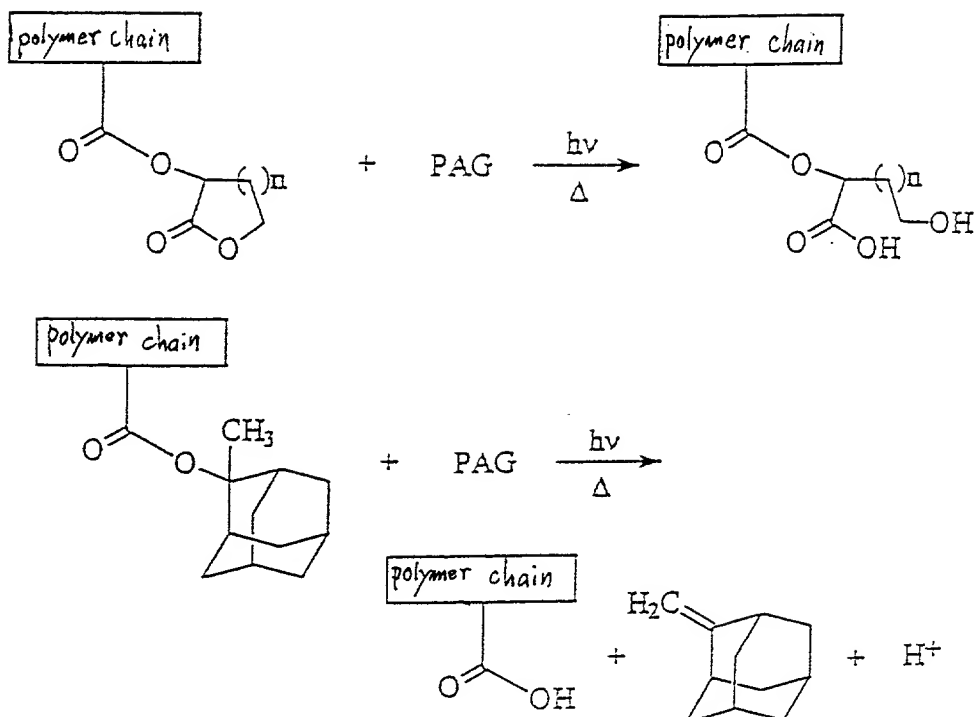
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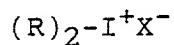
In the combination as represented by the foregoing copolymer, there is induced deprotection reaction that regenerates the protonic acid as a result of the exposure process, and the resist film shows a very high sensitivity. After the deprotection of the protected group, a carboxylic acid is generated. As the other lactone part is also soluble to alkalis, the exposed part of the resist film changes to be soluble to a basic aqueous solution. Thus, by applying a developing process conducted in a basic aqueous solution, a positive pattern is obtained in which the exposed part is dissolved. As such a developing process employs a change of the polarity occurring in the resist film, the pattern thus formed is substantially free from swelling.

In the chemical amplification resist of the present invention, it should be noted that it is possible to use a conventional PAG used in a chemical

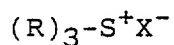
1 amplification resist for radiation sources such as far  
ultraviolet, vacuum ultraviolet or X-rays. While not  
limited, the PAG for use in the present invention  
includes the following:

5

(I) onium salts having a formula



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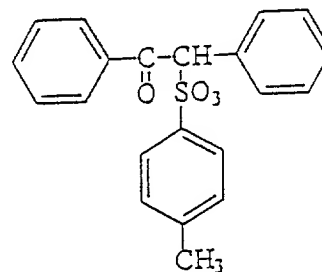
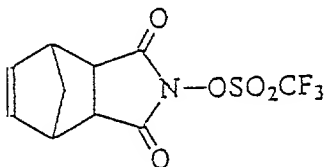


wherein R represents a substitutional or non-  
substitutional benzene ring or alicyclic group, while  
X represents  $BF_4$ ,  $PF_6$ ,  $AsF_6$ ,  $SbF_6$ ,  $CF_3SiI_3$ ,  $ClO_4$ , and  
15 the like.

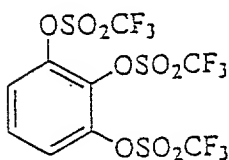
(II) sulfonic acid ester

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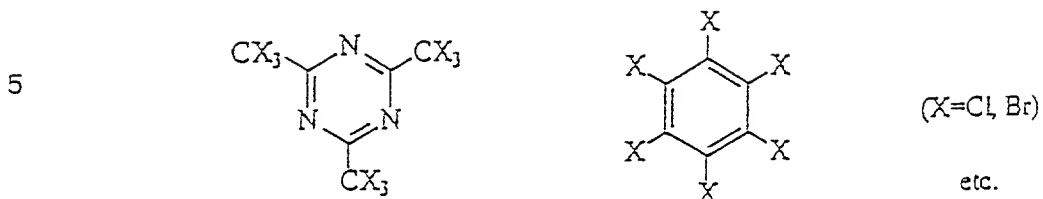


etc.

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1 (III) halides



10 The PAG noted above may be used in the resist composition of the present invention with various proportions. A proportion of 0.1 - 50 wt% (with respect to the polymer weight), more preferably 1 - 15 wt%, is recommended. In the case of the resist  
15 composition of the present invention, it is preferably to adjust the structure of the polymer as well as the structure and proportion of the PAG such that the resist film shows an absorbance of 1.75 or less.

It should be noted that the resist  
20 composition of the present invention is advantageously used in the form of a resist solution in which the foregoing acid-sensitive polymer and the PAG are dissolved into an organic solvent. The organic solvent may be selected, although not limited, from:  
25 ethyl lactate, methylamylketone, methyl-3-methoxypropionate, ethyl-3-ethoxypropionate, and propyleneglycolmethylether acetate. Further, two or more solvents may be mixed. While the proportion of the solvent with regard to the polymer is not limited,  
30 it is preferable to optimize the proportion such that a suitable viscosity for a successful spin coating process is obtained.

The resist solution thus formed may further contain an additional, auxiliary solvent. Such an  
35 auxiliary solvent is not necessary when the resist film is formed uniformly as a result of the spin coating process. On the other hand, when the

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1 uniformity of the coated resist film is poor, the  
quality of the resist film can be improved by adding  
such an auxiliary solvent to the foregoing primary  
solvent generally within the proportion of 1 - 30 wt%,  
5 more preferably 10 - 20 wt%. For the auxiliary  
solvent, a solvent selected from butyl acetate,  
 $\gamma$ (gamma)-butyrolactone, propyleneglycol methylether,  
and the like may be used.

The present invention further provides a  
10 process of forming a positive resist pattern on a  
substrate by using the foregoing resist composition.  
The formation of the resist pattern can be achieved as  
follows.

First, a resist film is formed using the  
15 resist composition of the present invention on a  
substrate. The substrate may be a substrate used  
commonly in the fabrication of semiconductor devices,  
or the like, and includes a Si substrate, a glass  
substrate, a non-magnetic ceramic substrate, and the  
20 like. The substrate may carry thereon various  
additional layers such as a  $\text{SiO}_2$  film, metal  
interconnection layer, interlayer insulation film,  
magnetic layer, and the like. Further, the substrate  
may carry thereon various interconnection patterns and  
25 circuit patterns. Further, the substrate may be the  
one that has been subjected to a hydrophobic  
processing for improving the adhesion of the resist  
film. Such a hydrophobic processing may be conducted  
according to the well established process that uses  
30 1,1,1,3,3,3-hexamethyl disilazane (HMDS).

The application of the resist composition is  
achieved by merely applying the resist solution  
directly on the substrate according to a commonly  
practiced process such as a spin-coating process, a  
35 rolling process, a dipping process, and the like.  
Among others, the spin-coating process is most  
convenient, and the resist film may be formed with a



- 1 thickness of 0.1 - 200  $\mu\text{m}$ . In the case of the  
exposure process conducted using by a KrF or an ArF  
excimer laser, it is preferable to set the thickness  
of the resist film in the range of 0.1 - 5  $\mu\text{m}$ .  
5 Further, the thickness of the resist film can be  
changed as necessary, depending on the particular  
application of the resist.

The resist film thus formed on the substrate  
is subjected to a prebaking process before exposing  
10 the resist film to the exposure radiation. The  
prebaking process is preferably conducted at a  
temperature of 60 - 180°C for a duration of 30 - 120  
seconds. Such a prebaking process can be achieved by  
using the heating means that is used commonly in the  
15 resist process. For example, the prebaking process  
may be conducted by using a hot plate, an infrared  
oven, or a microwave oven.

After the prebaking process, the resist film  
is exposed in an exposure system. The exposure system  
20 may any of optical exposure systems including far  
ultraviolet and deep ultraviolet exposure system, an  
X-ray exposure system, an electron beam exposure  
system, and the like. In the resist composition of  
the present invention, it is particularly advantageous  
25 to use a KrF excimer laser with the wavelength of 248  
nm or an ArF excimer laser with the wavelength of 193  
nm. In the description of the present invention,  
however, it should be noted that the phrase  
"radiation" encompasses any radiation produced by any  
30 radiation source noted above.

After the exposure process, the resist film  
is subjected to a PEB process, to induce a  
deprotection reaction of the protective group, while  
using the protonic acid as a catalyst. The PEB  
35 process can be achieved just like the prebaking  
process as long as the heat treatment is conducted  
within the range in which the deprotection reaction

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1 proceeds sufficiently. For example, the PEB process  
may be conducted at the temperature of 60 - 180°C for  
30 - 120 seconds. The condition of the PEB process  
5 may be adjusted depending on the desired pattern size,  
pattern profile, and the like.

After the PEB process, the resist film is  
developed in a basic aqueous solution. The basic  
aqueous solution may be applied to the resist film as  
a developer by using a developing apparatus, which may  
10 be any of a spin developer, a dip developer or a spray  
developer. The developer may be any of an aqueous  
solution of a Group I or Group II metal element or an  
aqueous solution of an organic salt free from a metal  
ion such as tetraalkylammonium hydroxide, wherein it  
15 is particularly preferable to use an aqueous solution  
of tetramethylammonium hydroxide (TMAH) that does not  
contain a metal element. In order to improve the  
efficiency of developing, it is also possible to add  
various additives to the developer such as a  
20 surfactant.

As a result of such a developing process,  
the exposed area of the resist is dissolved, and the  
unexposed area of the resist remains as a resist  
pattern.

25 Hereinafter, various embodiments of the  
present invention will be described with regard to the  
synthesis of the acid-sensitive polymer, preparation  
of the resist composition and formation of the resist  
pattern. The embodiments below, however, are only  
30 examples and the present invention is by no means  
limited to these specific embodiments.

#### [FIRST EMBODIMENT]

#### SYNTHESIS OF $\tau$ -BUTYLOLACTONE-2-YL METHACRYLATE

35 A three-neck flask of 200 ml size is dried  
thoroughly and filled with N<sub>2</sub>, after connecting  
thereto a dropping funnel, a calcium chloride tube and

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Next, 5.11g (48.9 mmol) of methacryloyl chloride previously held in the dropping funnel is introduced by a dropping process conducted for 1 hour, and the liquid thus obtained is stirred at a room temperature for 2 hours. The resultant solution is then taken into a separating funnel of a 300 ml size, and the solution thus taken is washed with 100 ml of water, followed by washing with a saturated sodium chloride water. Thereby, the water layer is extracted three times with methylene chloride, and the extracts are added to the organic layer. The organic layer thus collected is then dried over anhydrous sodium sulfate, and filtered through a filter paper. As a result of the filtering, a brownish oil is obtained, and the brownish oil is purified by a silica gel column chromatography. As a result of the purification, a colorless transparent oil is obtained as a target product.

yield 7.25g (78.1%)

<sup>1</sup>H NMR(CDCl<sub>3</sub>, d, J in Hertz): 1.98(3H,s), 2.35(1H,m), 2.76(1H,m), 4.35(1H,m), 4.51(1H,m), 5.43(1H,t,J=6.5), 5.70(1H,s), 6.22(1H,s), wherein s in the bracket represents singlet, d represents doublet and m represents multiple.

SYNTHESIS OF A COPOLYMER OF  $\tau$ -BUTYLOLACTONE-2-YL

A flask of 100 ml size is used to hold 3g  
(17.6 mmol) of  $\gamma$ -butyrolactone-2-yl

Next, the precipitate is filtered by using a glass filter and the resin thus filtered is dried in a vacuum oven at 45°C for 6 hours. The resin thus obtained is then dissolved into THF. After repeating the precipitation purification twice by using methanol, the resin is dried in the vacuum oven at 45°C for 18 hours. As a result, a whitish resin power is obtained with a yield of 5.35g (82.2%).

20 Mw:14,900, Mw/Mn=1.83 (in terms of standard polystyrene)

IR(KRS-5,  $\text{cm}^{-1}$ ): 2913, 1791, 1737, 1261, 1147, 1103

RESIST PATTERN FORMATION

The resist solution thus obtained is then filtered by a teflon membrane filter of 0.2  $\mu\text{m}$  size

1 and spinn onto a Si substrate processed by HMDS, to  
form a resist film. The resist film thus formed is  
subjected to a prebaking process at 120°C for 60  
seconds, and a resist film having a thickness of 0.7  
5  $\mu\text{m}$ .

The resist film thus obtained is then  
subjected to an exposure process, in which the  
exposure process is conducted by a KrF excimer laser  
stepper having a numerical aperture of 0.45.

10 After the exposure, the resist film is  
subjected to a PEB process at a temperature of 110°C  
for 60 seconds, and a resist pattern is developed by  
applying a 2.38% TMAH (tetramethyl ammonium  
hydroxide) developer. After the development, the  
15 resist pattern was rinsed by a deionized water.

It was confirmed that, as a result of the  
exposure conducted with a dose of 30.0 mJ/cm<sup>2</sup>, a line-  
and-space pattern of 0.25  $\mu\text{m}$  pitch is successfully  
resolved.

20

[FOURTH EMBODIMENT]

#### RESIST PATTERN FORMATION

The resist solution of the third embodiment  
is applied on a hydrophobic Si substrate surface  
25 processed by HMDS, similarly to the case of the third  
embodiment, to form a resist film with a thickness of  
0.4  $\mu\text{m}$ . The resist film is then subjected to an  
exposure process conducted by using an ArF excimer  
laser stepper having a numerical aperture (NA) of  
30 0.55. After the exposure, the resist film is  
subjected to a PEB process conducted at 100°C for 60  
seconds, followed by a developing process using a  
2.38% TMAH developer, to form a resist pattern. The  
resist pattern thus formed is rinsed by a deionized  
35 water.

According to the experiment of the present  
embodiment, it was confirmed that a line-and-space

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1 pattern of 0.20  $\mu\text{m}$  pitch is successfully resolved when  
an exposure dose of 26  $\text{mJ}/\text{cm}^2$  is used.

[FIFTH EMBODIMENT]

5 FORMATION OF A RESIST PATTERN

The copolymer synthesized in the foregoing  
second embodiment is dissolved to form a 15wt% PGMEA  
solution, and a resist solution is formed by adding 2  
wt% of diphenyliodonium trifluoromethanesulfonate with  
10 respect to the resin, to the foregoing PGMEA solution.  
The resist solution thus obtained is applied on a  
surface of a Si substrate processed by HMDS by a spin  
coating process. After a prebaking process conducted  
at 120°C for 60 seconds, a resist film having a  
15 thickness of 0.4  $\mu\text{m}$  is obtained.

The resist film is then subjected to an  
exposure process in an ArF exposure system, followed  
by a PEB process conducted at 100°C for 60 seconds.  
The resist film thus exposed is then developed by a  
20 2.38% TMAH developer, and rinsed by a deionized water.

According to the present embodiment, it was  
confirmed that a line-and-space pattern of 0.20  $\mu\text{m}$   
pitch is successfully resolved when an exposure dose  
of 20  $\text{mJ}/\text{cm}^2$  is used.

25

[SIXTH EMBODIMENT]

SYNTHESIS OF A COPOLYMER OF  $\tau$ (gamma)-BUTYLOLACTONE-2-  
YL METHACRYLATE AND ISOBORNYL METHACRYLATE

A flask of 100 ml size is used to hold 5.0g  
30 (29.4 mmol) of  $\tau$ -butylolactone-2-yl methacrylate,  
6.54g (29.4 mmol) of isobornyl methacrylate, 19.6 ml  
of dioxane and 1.44g (8.8 mmol) of  
azobisisobutyronitrile (AIBN), together with a teflon-  
cated stirrer bar, and the mixture in the flask is  
35 stirred by using the stirrer bar in an  $\text{N}_2$  environment  
at a temperature of 70°C for 8 hours. A resultant  
fluid is diluted by THF and added dropwise into 1 l of

1    methanol containing a small amount of hydroquinone, to  
       form a precipitate.

Next, the precipitate thus formed is filtered by using a glass filter and dried under a 0.1 mmHg pressure at 45°C for 16 hours. The resin thus obtained is then dissolved again into THF, and the foregoing filtering and drying process are repeated twice. As a result of the foregoing process, a whitish resin power is obtained.

By conducting a  $^1\text{H}$ NMR analysis, it was confirmed that the resin contains lactone and isobornyl with a ratio of 49: 51. The copolymer thus obtained shows a transmittance of 96% at 248 nm and a transmittance of 65% at 193 nm, provided that the polymer film is formed on an  $\text{SiO}_2$  substrate with a thickness of 1  $\mu\text{m}$ .

yield 8.61g (80%)  
Mw:15,400 (in terms of standard polystyrene)  
dispersion 1.82  
IR(KRS-5,  $\text{cm}^{-1}$ ): 2961, 1792, 1736, 1250,  
1163, 1102

[SEVENTH EMBODIMENT]  
25 FORMATION OF RESIST PATTERN

The copolymer synthesized in the previous sixth embodiment is dissolved to form a 145 wt% PGMEA solution. Further, a resist is formed by adding 2 wt% of triphenylsulfonium trifluoromethanesulfonate with respect to the resin, to the foregoing PGMEA solution. The solution further contains 6 wt% of  $\gamma$ -butyrolactone as an auxiliary solvent.

The resist solution thus obtained is then applied on a surface of a Si substrate processed by HMDS and subjected to a prebaking process conducted at 120°C for 60 seconds. Thereby, a resist film having a thickness of 0.4  $\mu\text{m}$  is formed.





1           Next, an ion implantation process is  
conducted while using the gate electrode as a mask, to  
form a  $N^-$ -type diffusion region 6 in the substrate 1.

          Next, in the step of FIG.1C, the resist  
5   pattern is removed and an  $SiO_2$  film 7 is formed on the  
entire surface of the structure of FIG.1B by a CVD  
process.

          The  $SiO_2$  film 7 is then subjected to an  
anisotropic etching process acting generally  
10   perpendicularly to the principal surface of the  
substrate 1 in the step of FIG.1D, to form a side wall  
insulation film 8. Further, an ion implantation  
process is conducted while using the gate electrode  
and the side wall insulation film as a mask, to form  
15    $N^+$ -type diffusion region 9 in the substrate 1.

          The  $N^+$ -type diffusion region 9 thus formed  
is then activated in the step of FIG.1E by conducting  
a thermal annealing process in an  $N_2$  atmosphere,  
followed by a thermal oxidation process to form an  
20   oxide film 10 on the exposed surface of the diffusion  
region 9.

          Further, in the step of FIG.1F, an  
interlayer insulation film 11 is deposited on the  
structure of FIG.1E and a resist film of the present  
25   invention is applied on the interlayer insulation film  
11 thus formed.

          After a prebaking process of the resist  
film, an exposure process for exposing a contact hole  
corresponding to the gate electrode is conducted by  
30   using an ArF excimer laser exposure system. After a  
PEB process, the resist film is subjected to a  
developing process conducted by using an alkaline  
developing liquid, and a minute contact hole having a  
diameter of  $0.20\ \mu m$  is successfully obtained.

35   Further, the resist pattern is removed, and an Al  
wiring pattern 12 is provided on the interlayer  
insulation film 11 in contact with the gate electrode



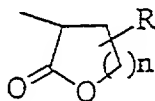
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a carboxyl group bonding to a side chain of said polymer main chain, said carboxyl group having a protective group; and

15

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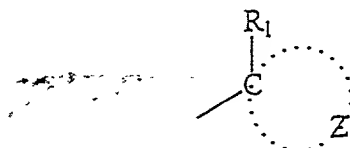
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2. An acid-sensitive polymer compound as claimed in claim 1, wherein said lactone part is formed of 2-hydroxy- $\gamma$ (gamma)-butyrolactone.

35

1           3. An acid-sensitive polymer compound as  
            claimed in claim 1, wherein said acid-sensitive  
            polymer includes a monomer unit selected from a group  
            consisting of acrylate and methacrylate monomer unit,  
5           a vinylphenol monomer unit and an N-substituted  
            maleimide monomer unit.

10  
            4. An acid-sensitive polymer compound as  
            claimed in claim 1, wherein said additional acidic  
            functional group includes an additional carboxyl group  
            having an acid-cleavable protective group, said acid-  
15           cleavable protective group having a formula of



20  
            wherein R<sub>1</sub> represents an alkyl group having a straight  
            chain or a branched chain including 1 - 4 carbon  
            atoms, said alkyl group being any of a substituted  
            group and an unsubstituted group, and wherein Z<sub>1</sub>  
25           represents a plurality of atoms necessary to complete  
            an alicyclic hydrocarbon group together with the  
            carbon atoms connected to R<sub>1</sub>.

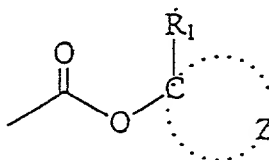
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            5. An acid-sensitive polymer compound as  
            claimed in claim 1, wherein said additional functional  
            group includes a monomer unit having an ester group,  
35           said ester group including a polycyclic alicyclic  
            hydrocarbon part that causes a deprotection in  
            response to an acid produced by a photoacid generator.

1           6. An acid-sensitive polymer compound as  
 claimed in claim 5, wherein said polycyclic alicyclic  
 hydrocarbon part includes an adamantyl group or a  
 norbornyl group.

5

10           7. An acid-sensitive polymer compound as  
 claimed in claim 4, wherein said additional carboxyl  
 group having a formula of:



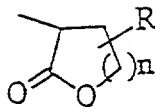
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wherein R<sub>1</sub> represents an alkyl group having a straight  
 chain or a branched chain including 1 - 4 carbon  
 atoms, said alkyl group being any of a substituted  
 group and an unsubstituted group, and wherein Z<sub>1</sub>  
 20 represents a plurality of atoms necessary to complete  
 an alicyclic hydrocarbon group together with the  
 carbon atoms connected to R<sub>1</sub>.

25

8. A resist composition, comprising:  
 an acid-sensitive film-forming polymer  
 insoluble to an alkaline solution; a carboxyl group  
 30 bonding to a side chain of said polymer's main chain,  
 said carboxyl group having a protective group; and an  
 additional acidic functional group bonding to a side  
 chain of said polymer main chain, said acidic  
 functional group having an acid-cleavable protective  
 35 group; said carboxyl group having, as said protective  
 group, a lactone structure represented by a formula

1



5

wherein n is an integer of 1 - 4, and R represents any of a hydrogen atom, an alkyl group, an alkoxy group or an alkoxy carbonyl group and bonding to an arbitrary position of said lactone structure excluding a second position forming an ester bonding; and

10

a photoacid generator causing a decomposition in response to an absorption of a radiation, said photoacid generator releasing an acid that causes a deprotection of said acid-cleavable protective group in response to said decomposition;

15

said resist composition becoming soluble to said alkaline solution after said acid-cleavable protective group has caused said deprotection.

20

9. A resist composition as claimed in claim 8, wherein said lactone part is formed of 2-hydroxy- $\gamma$ (gamma)-butyrolactone.

25

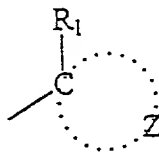
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10. A resist composition as claimed in claim 8, wherein said acid-sensitive polymer includes a monomer unit selected from a group consisting of acrylate and methacrylate monomer unit, a vinylphenol monomer unit and an N-substituted maleimide monomer unit.

35

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- 1            11. A resist composition as claimed in  
claim 8, wherein said additional acidic functional  
group includes an additional carboxyl group having an  
acid-cleavable protective group, said acid-cleavable  
5        protective group having a formula of



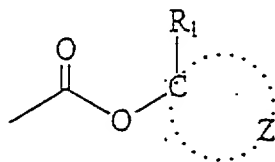
- 10        wherein R<sub>1</sub> represents an alkyl group having a straight  
chain or a branched chain including 1 - 4 carbon  
atoms, said alkyl group being any of a substituted  
group and an unsubstituted group, and wherein Z<sub>1</sub>  
represents a plurality of atoms necessary to complete  
15        an alicyclic hydrocarbon group together with the  
carbon atoms connected to R<sub>1</sub>.

- 20            12. A resist composition as claimed in  
claim 8, wherein said additional functional group  
includes a monomer unit having an ester group, said  
ester group including a polycyclic alicyclic  
25        hydrocarbon part that causes a deprotection in  
response to an acid produced by a photoacid generator.

- 30            13. A resist composition as claimed in  
claim 12, wherein said polycyclic alicyclic  
hydrocarbon part includes an adamantyl group or a  
norbornyl group.

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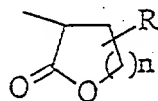
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1           17. A resist composition as claimed in  
claim 16, further including a solvent selected from a  
group consisting of butyl acetate,  $\gamma$ (gamma)-  
butyrolactone and propyleneglycol methylether as an  
5           auxiliary solvent.

10           18. A method of forming a resist pattern,  
comprising the steps of:  
applying a resist composition on a substrate  
to form a resist film, said resist composition  
comprising:

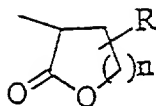
15           an acid-sensitive polymer compound  
insoluble to an alkaline solution, said acid-  
sensitive polymer compound comprising a film-  
forming polymer; a carboxyl group bonding to a  
side chain of said polymer main chain, said  
20           carboxyl group having a protective group; and an  
additional acidic functional group bonding to a  
side chain of said polymer main chain, said  
acidic functional group having an acid-cleavable  
protective group; said carboxyl group having, as  
25           said protective group, a lactone structure  
represented by a formula



30           wherein n is an integer of 1 - 4, and R  
represents any of a hydrogen atom, an alkyl  
group, an alkoxy group and an alkoxy carbonyl  
group and bonding to an arbitrary position of  
35           said lactone structure excluding a second  
position forming an ester bonding; and  
a photoacid generator causing a



1



5

wherein n is an integer of 1 - 4, and R represents any of a hydrogen atom, an alkyl group, an alkoxy group or an alkoxycarbonyl group and connected to an arbitrary position of said lactone structure excluding a second position forming an ester bonding; and

10

a photoacid generator causing a decomposition in response to an absorption of a radiation, said photoacid generator releasing an acid that causes a deprotection of said acid-cleavable protective group in response to said decomposition;

15

said resist composition becoming soluble to said alkaline solution after said acid-cleavable protective group has caused said deprotection;

20

exposing said resist film to an exposure radiation that induces said decomposition in said photoacid generator;

25

developing said resist film, after said step of exposure, by a basic solution to form a resist pattern; and

etching said substrate while using said resist pattern as a mask.

30

20. A method as claimed in claim 19, wherein said step of forming said resist film includes a step of applying a solution of said resist composition on said substrate with a thickness of 0.1

35

1     - 2  $\mu$ m.

5

21. A method as claimed in claim 19,  
wherein said step of exposing said resist film is  
conducted by a KrF excimer laser.

10

22. A method as claimed in claim 19,  
wherein said step of exposing said resist film is  
15 conducted by an ArF excimer laser.

20

23. A method as claimed in claim 19,  
wherein said step of developing is conducted by using  
an alkaline aqueous solution.

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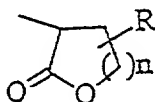
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2025 RELEASE UNDER E.O. 14176

1     ABSTRACT OF THE DISCLOSURE

          A resist composition includes a polymer  
principal chain, a carboxyl group having a protective  
group and bonding to a side chain of the polymer main  
5     chain, and an additional acidic functional group  
having an acid-cleavable protective group and bonding  
to a side chain of the polymer main chain, wherein the  
carboxyl group has a lactone structure represented by  
a formula

10



(wherein n is an integer of 1 - 4, and R represents  
15     any of a hydrogen atom, an alkyl group, an alkoxyl  
group and an alkoxycarbonyl group and connected to an  
arbitrary position of said lactone structure excluding  
a second position forming an ester bonding) as the  
protective group.

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04527-01998  
2000/04/20

# Declaration For U.S. Patent Application

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled  
(Insert Title) POLYMER COMPOUND FOR A CHEMICAL AMPLIFICATION RESIST AND A  
FABRICATION PROCESS OF A SEMICONDUCTOR DEVICE USING SUCH A CHEMICAL  
the specification of which is attached hereto unless the following is checked: AMPLIFICATION RESIST

☐ was filed on \_\_\_\_\_ as United States Application Number or PCT International  
Application Number \_\_\_\_\_ and was amended on \_\_\_\_\_  
(if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 (a) - (d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

(List prior foreign applications. See note A on back of this page)	Pat. Appln. No. 9-165935	Japan	23/June/1997	Priority Claimed <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
	_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes <input type="checkbox"/> No
	_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes <input type="checkbox"/> No
	_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes <input type="checkbox"/> No
	_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> Yes <input type="checkbox"/> No

(See note B on back of this page)

☐ See attached list for additional prior foreign applications

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below.

_____ (Application Number)	_____ (Filing Date)
_____ (Application Number)	_____ (Filing Date)

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of the application:

(List Prior U.S. Applications)	_____ (Application Serial Number)	_____ (Filing Date)	_____ (Status) (patented, pending, abandoned)
	_____ (Application Serial Number)	_____ (Filing Date)	_____ (Status) (patented, pending, abandoned)

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Title 18 of the United States Code, § 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor (given name, family name) Koji Nozaki

(See note C above) Inventor's Signature Koji Nozaki Date January 5, 1998

Residence Kawasaki-shi, Kanagawa, Japan Citizenship Japan

Post Office Address c/o FUJITSU LIMITED, 1-1, Kamikodanaka 4-chome, Nakahara-ku, Kawasaki-shi, Kanagawa, 211 Japan

Full name of second inventor (given name, family name) Ei Yano

Inventor's Signature Ei Yano Date January 5, 1998

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Full name of third inventor (given name, family name) \_\_\_\_\_

Inventor's Signature \_\_\_\_\_ Date \_\_\_\_\_

Residence \_\_\_\_\_ Citizenship \_\_\_\_\_

Post Office Address \_\_\_\_\_

Full name of fourth inventor (given name, family name) \_\_\_\_\_

Inventor's Signature \_\_\_\_\_ Date \_\_\_\_\_

Residence \_\_\_\_\_ Citizenship \_\_\_\_\_

Post Office Address \_\_\_\_\_

Full name of fifth inventor (given name, family name) \_\_\_\_\_

Inventor's Signature \_\_\_\_\_ Date \_\_\_\_\_

Residence \_\_\_\_\_ Citizenship \_\_\_\_\_

Post Office Address \_\_\_\_\_

Full name of sixth inventor (given name, family name) \_\_\_\_\_

Inventor's Signature \_\_\_\_\_ Date \_\_\_\_\_

Residence \_\_\_\_\_ Citizenship \_\_\_\_\_

Post Office Address \_\_\_\_\_

Full name of seventh inventor (given name, family name) \_\_\_\_\_

Inventor's Signature \_\_\_\_\_ Date \_\_\_\_\_

Residence \_\_\_\_\_ Citizenship \_\_\_\_\_

Post Office Address \_\_\_\_\_

Full name of eighth inventor (given name, family name) \_\_\_\_\_

Inventor's Signature \_\_\_\_\_ Date \_\_\_\_\_

Residence \_\_\_\_\_ Citizenship \_\_\_\_\_

Post Office Address \_\_\_\_\_

FIG. 1A

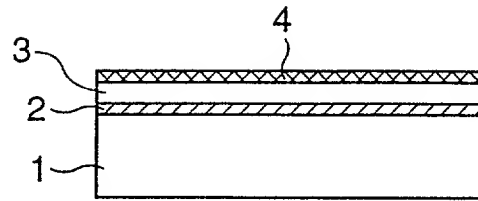


FIG. 1B

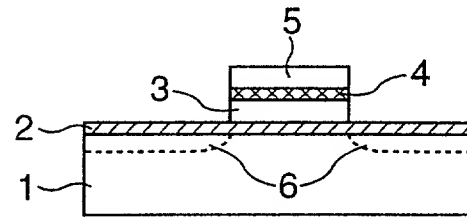


FIG. 1C

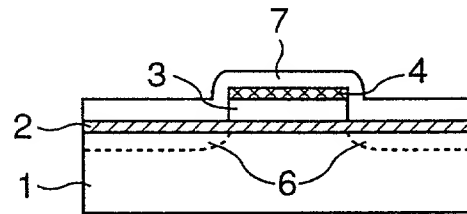


FIG. 1D

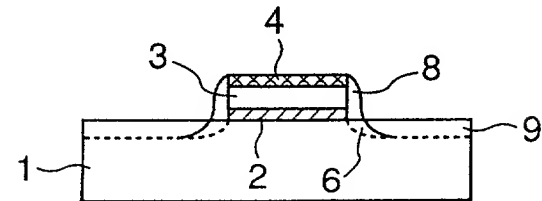


FIG. 1E

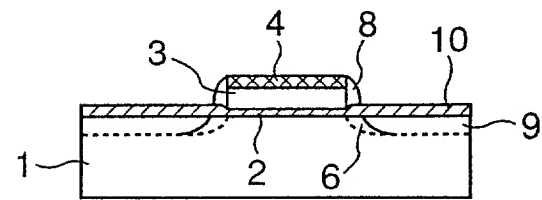


FIG. 1F

